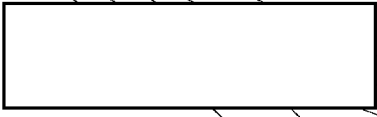


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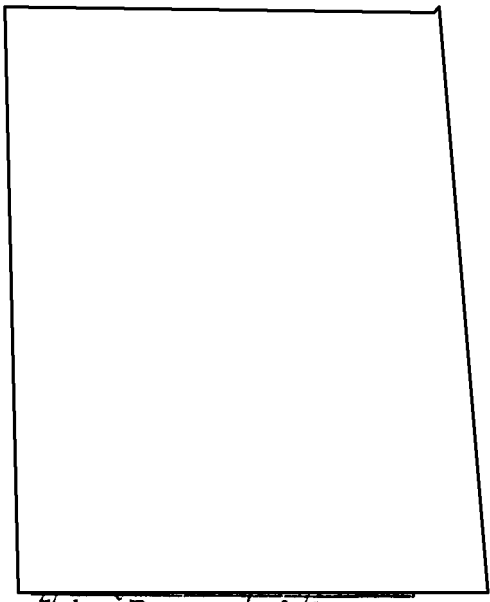
PERFORMANCE EVALUATION

OF

THE U-2R MODEL AIRPLANE

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Prepared By:



Reviewed By:

Approved By:

John Parangosky

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NRO review(s) completed.

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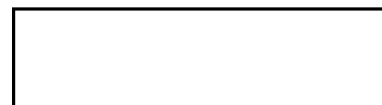
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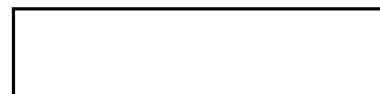
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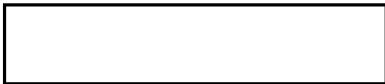


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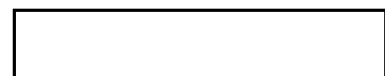
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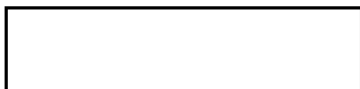
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SUMMARY

1. An independent performance evaluation of the U-2R by Deputy for Technology/OSA indicates:

a. Good agreement with the Lockheed performance estimates (Ref. Tables I, II, III, pages 11, 12, and 13).

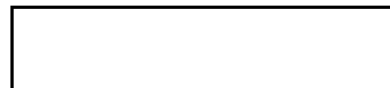
b. Compared with the U-2C at a similar take-off gross weight (U-2C @ 24,200 lbs., U-2R @ 26,790 lbs.), the U-2R has increased the average maximum altitude by about 4,790 feet [redacted] without compromise in range (2720 to 2790 n.m.) (Ref Figure 3 page 20).

c. Compared with the U-2C at normal take-off gross weight (U-2C @ 22,900 lbs., U-2R @ 30,130 lbs.), the U-2R has increased the unrefueled maximum altitude cruise range by 1499 N.M. (from 2,460 N.M. [redacted]) with an increased average maximum altitude of about 2,940 feet [redacted] (Ref Figure 2 page 19).

d. The U-2R with a maximum overload fuel take-off gross weight of 36,750 lbs. has an unrefueled maximum altitude cruise range of [redacted] with maximum cruise altitudes from 65,700 ft. to [redacted]. Because of "Badlands" (Engine EGT limited to 485°C between 40,000 and 60,000 feet altitude) the initial cruise altitude of 65,700 ft. will not be reached until 1,114 nautical miles after take-off. (Ref. Figure 1 page 18.) Without "Badlands" effect, an initial cruise altitude of 65,000 ft. would be reached at 657 N.M. after take-off. (Ref Table 1, page 11).

e. "Badlands" has little appreciable effect on the U-2R "Reduced" and "Normal" take-off gross weight profiles as summarized above in paragraphs b and c. Imposition of "Badlands" was made by Deputy for Technology for the sake of conservatism since the degree to which

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EGT will be limited during climb must await U-2R flight test with the properly contoured new inlet duct matched to the P-13B engine. Lockheed performance estimates do not include the "Badlands" effect. This report shows all profiles with and without "Badlands".

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2. [ ] because of their varying degradations on propulsion performance should be examined closely by Pratt & Whitney early in the program in order to define the optimum system. This performance evaluation does not include the effect of infra-red suppression techniques as none were included in the contractor's proposal.

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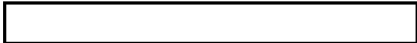


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GENERAL INTRODUCTION

1. The scope of this report is limited to a performance evaluation of the U-2R aircraft with a payload of 945 lbs. including camera and EWS as presented in Lockheed Reports Nos. SP-937 dated 27 December 1965 and SP-973 dated 12 April 1966. Evaluation of such areas as airframe structure, payload configuration, cockpit configuration, stability, navigation, hydraulic, electrical, and other systems is excluded.

2. Vehicle performance is estimated by scaling from demonstrated U-2C performance and is not based upon any U-2R-wind tunnel tests. It is also based heavily upon the uninstalled performance calibration of the J75-P-13B engine (conducted at the Naval Air Turbine Test Center). Installation correction factors were determined from flight test of a U-2C aircraft (article 349) equipped with the J75-P-13B engine.

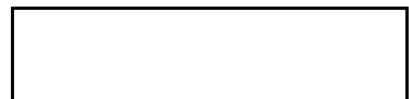
3. Any impact resulting from  devices, additional ECM weight, external antennae, etc., will degrade the performance below that estimated in this report.

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4. The U-2R operation from naval aircraft carriers is expected to be comparable to that of the U-2G.

5. As the program develops, and further information becomes available, this document will be revised accordingly at appropriate time intervals.

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PROPULSION SYSTEMAnalysis of J75-P-13B EngineGeneral

The engine proposed for use in the U-2R airplane is the Pratt & Whitney J75-P-13B and is an uprated and improved version of the J75-P-13 engine. Primarily through an increase in airflow and turbine inlet temperature, this engine provides 10 to 15% more thrust at maximum altitude cruise than the older P-13 engine. Engine suitability is certified by Appendix B of Pratt & Whitney Specification Number N-2614-G. Engine performance presented in the specification is based on actual performance calibrations conducted at the U.S. Naval Air Turbine Test Station (NATTS), Trenton, New Jersey.

Inlet

The air induction system for the U-2R will be an improved system incorporating both the new opened up inlet now being incorporated on the "C" articles, plus an improved contour inlet duct. The calculation procedure used to verify the installed engine performance presented in reference 1, and described further in the Engine section of this discussion, utilized inlet recovery data already achieved and measured, in flight, on the U-2C aircraft with the opened up inlet. These calculations do not account for the further improvement in inlet recovery which should be realized with the recontoured duct in the U-2R. The inlet recovery corrections applied to the uninstalled specification performance therefore add a slight note of pessimism to the estimated installed engine performance.

Engine

The improved performance, of the U-2R aircraft, has been made possible primarily by the availability of the J75-P-13B engine, which provides increased thrust for climb and cruise over the older P-13 version of the engine. The primary question remaining with regard to engine performance, concerns the possibility of a requirement for reduced throttle operation

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through the so-called "Badlands" (an area from 40,000 feet to 60,000 feet of altitude) as is currently in effect on the U-2C aircraft with the J75-P-13 engine. Comments regarding the effect of reduced throttle operation in the "Badlands" area on the performance of the airplane are contained in the airplane performance section of this report. The current operational procedure for the U-2C equipped with the P-13 engine, is to throttle back to an EGT (exhaust gas temperature) of 485°C at altitudes from 40,000 to 60,000 feet. Although aircraft performance computations for the U-2R do show the effect of throttling back to this EGT, there is no definite indication at this time, that throttling back to this extent will be required. Throttling back however, to some EGT level lower than maximum allowable of 665°C probably will be required. Successful climbs through "Badlands" have already been made with the J75-P-13B engine in the U-2C (article 349) with the so-called Prototype B inlet ducts, i.e., the opened up area inlets at EGT's of 540°C and 600°C. One smooth climb was made at 610°C, but a second attempt was unsuccessful due to an engine rumble which may have been compressor instability. Seven flights have been completed at maximum EGT of 665°C above 60,000 feet, and no engine problems were encountered. The new (recontoured) inlet duct planned for the U-2R should result in some improvement in engine performance and stall margin over that experienced in the above referenced flights. Final climb power settings for the U-2R aircraft, however, cannot be established until the article has been flight tested and a final climb schedule based on maximum allowable EGT and/or EPR (engine pressure ratio) is determined. The only conclusion that can be drawn, at this time, is that the 485°C EGT limitation from 40,000 to 60,000 feet is not significantly detrimental to the performance of the U-2R with the exception of the maximum internal fuel (overload) maximum altitude mission. All indications are that a somewhat higher than the 485°C EGT limitation should be possible.

As a part of the effort to obtain maximum possible climb performance for the installed engine, a quality review must be conducted of the engine pressure ratio gages (EPR gages) used by the pilot to monitor engine power setting. All gages provided should represent the highest level of accuracy attainable and each gage should be calibrated accurately against a standard pressure source. This will allow the engine and airframe contractors to arrive at an EPR schedule, on the

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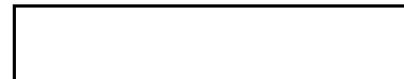
basis of flight test experience, which will provide maximum engine climb power with a reasonable margin of safety from engine stall. If a substantial additional margin of safety is required to allow for a wide band of EPR gage errors and unknown calibrations of gages used in flight test, then the maximum engine climb performance will suffer accordingly. Pending a U-2R go-ahead, Deputy for Technology will undertake the necessary action to assure that the highest quality of EPR gages can be obtained, resulting in the best possible engine performance on an EPR basis.

Computations of installed engine performance (thrust and specific fuel consumption) were made in sufficient detail to check the values of installed thrust and TSFC, at and near maximum power, presented by LAC in reference 1. Maximum thrust values check those presented by Lockheed within approximately 1% and values of TSFC are generally somewhat better than those presented by LAC. This subject is discussed in more detail in the Appendix where curves comparing D/TECH estimates with those of Lockheed are presented as Figure A-1.



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AIRCRAFT PERFORMANCEU-2R MAXIMUM ALTITUDE MISSIONSNO "BADLANDS"

The term "Badlands" is described as the region between 40,000 and 60,000 feet of altitude where the Exhaust Gas Temperature (EGT) of the engine has to be limited to 485°C, to prevent encountering difficulties such as engine roughness, compressor stall, or flame-out. The climb and cruise performance for the U-2R without the "Badlands" effect was calculated in detail (see Appendix) to compare to the values computed by Lockheed and presented in Reference 2. Three take-off gross weight (T.O.G.W.) configurations were investigated: "Overload", "Normal", and "Reduced".

"Overload" (T.O.G.W. = 36,750 lbs.): Assumes a maximum fuel capacity of 19,350 lbs.

"Normal" (T.O.G.W. = 30,130 lbs.): Assumes a partial fuel load of 12,730 lbs.

"Reduced" (T.O.G.W. = 26,790 lbs.): Assumes a partial fuel load of 9,390 lbs.

Two values of fuel reserve (100 and 150 gallons) were used by D/TECH to show the impact of fuel reserve allowance on mission performance. As seen from Tables I, II, and III, D/TECH calculated estimates of aircraft performance are in very good agreement with the Lockheed estimates.

A breakdown of the D/TECH mission performance summaries shown in Tables I, II, and III, is given in Part I of Tables IV, V, and VI, correspondingly.

U-2R MAXIMUM ALTITUDE MISSIONSWITH "BADLANDS"

The climb and cruise performance for the U-2R with the "Badlands" effect was calculated in detail, as shown in the

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Appendix. Lockheed did not estimate the impact of 485°C EGT limitation between 40,000 and 60,000 feet on the mission performance of the U-2R. Only mission performance without the "Badlands" effect was presented by Lockheed in Reference I and 2.

Three Take-off gross weight configurations were investigated: "Overload", "Normal", and "Reduced". The mission performance with "Badlands" for maximum altitude is presented in Part II of Tables IV, V, and VI. From the above mentioned tables, it is interesting to notice the "Badlands" effect on the altitudes, distance, and time. For the "Overload" configuration it can be seen that the 485°C EGT limitation, between 40,000 and 60,000 feet allows the aircraft to reach only an altitude of 59,200 feet at the end of climb. This is caused by the associated thrust reduction with EGT limitation. The airplane does not have sufficient thrust to keep on climbing at this weight and is forced to cruise-climb from 59,200 up to 60,000 feet of altitude. The maximum thrust available (with the EGT limitation) during this cruise-climb is equal to the drag ( $T=D$ ). The cruise-climb below 60,000 feet of altitude is accomplished by the reduction in aircraft weight due to fuel consumption. When the airplane has reached 60,000 feet of altitude, the 485°C EGT restriction is removed, and a higher thrust is available, enabling the aircraft to commence a "Secondary Climb" to maximum altitude.

The "Badlands" effect is not as significant for the "Normal" and "Reduced" take-off gross weight configurations, because the aircraft weight and corresponding drag during the initial climb is low enough to be relatively insensitive to the reduced thrust. This low level of drag leaves an excess thrust ( $T-D$ ) available for climb to 60,000 feet of altitude, where the 485°C EGT limitation is removed and a thrust recovery is obtained.

#### COMPARISON OF U-2R MAXIMUM ALTITUDE MISSIONS WITH AND WITHOUT "BADLANDS"

The Overload Take-off Mission data presented in Table IV, clearly indicates the reduction in altitude resulting from the "Badlands" thrust limitation. However, the range with "Badlands" is greater than without "Badlands" since the altitude limitation (imposed by the thrust limitation) results in the aircraft cruising at essentially the maximum

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range factor from 59,200 feet to 60,000 feet of altitude. Because of "Badlands" the initial maximum cruise altitude of 67,500 feet would be reached 1,114 nautical miles from take-off. Without "Badlands" an initial maximum cruise altitude of 65,000 feet would be reached 657 nautical miles from take-off. The data for the Normal Take-off Weight Mission, presented in Table V, also shows a greater range with "Badlands" than without "Badlands," and essentially there is no difference in cruise altitudes. The two missions differ in the distance at which cruise is initiated, i.e., 339 n.m. without "Badlands" compared to 417 n.m. with "Badlands." Consequently, without the 485°C EGT limitation, the aircraft reaches its maximum cruise altitude 78 n.m. sooner than with the limitation. Finally, the Reduced Take-off Weight Mission with "Badlands," Table VI, results in greater range and higher initial cruise altitude than without "Badlands," because the amount of fuel used during climb is larger (resulting in a lower aircraft weight). Here again, the primary advantage without the thrust limitation is the shorter time required to reach cruise altitude. Specifically, without the "Badlands" limitation, the aircraft reaches cruise altitude 136 n.m. sooner than with the limitation.

#### MAXIMUM ALTITUDE MISSION PROFILES

##### U-2C VERSUS U-2R

A comparison of the maximum altitude mission performance, between the U-2C and U-2R, was made to determine the performance gains obtained with the U-2R. The U-2R performance data, utilized in this comparison, is that with "Badlands." The data presented for the U-2C is based on current flight results, and were obtained from the Operations Division (IDEALIST).

Three different loading configurations for the U-2R were compared to two for the U-2C.

"Overload" Mission Performance - The "Overload" take-off gross weight configuration for the U-2R (T.O.G.W. = 36,750 lbs.), is compared to the overload take-off gross weight configuration of the U-2C (T.O.G.W. = 24,200 lbs; slipper tanks on) as shown in Figure 1.

The time and fuel used for these missions are presented in Tables IV and VII.

"Normal" Mission Performance - The "Normal" take-off gross weight configuration for the U-2R (T.O.G.W. = 30,130 lbs.), is compared

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to the normal take-off gross weight configuration of the U-2C (T.O.G.W. = 22,900 lbs; slipper tanks off) as shown in Figure 2.

The time and fuel used for these missions are presented in Tables V and VII.

U-2C "Overload" versus U-2R "Reduced" T.O.G.W. - In Figure 3 the mission performance for the Overload take-off gross weight configuration of the U-2C (T.O.G.W. = 24,200 lbs; slipper tanks on), is compared to the "Reduced" take-off gross weight configuration of the U-2R (T.O.G.W. = 26,790 lbs.). The time and fuel used for these missions are presented in Tables VI and VII.

### CONCLUSIONS

The "Badlands" effect is very apparent for the "Overload" configuration for the U-2R (Figure 1). The range obtained for the U-2R with respect to the U-2C, is more than doubled in this configuration, but with the associated penalty of lower initial cruise altitudes than the U-2C. It is also important to realize that the U-2R cruises at a higher speed than the U-2C.

The "Normal" take-off gross weight configuration of the U-2R, when compared to the U-2C (Figure 2), indicated that the range of the U-2R is 61% better, and that the average maximum cruise altitude has been improved by approximately 2,940 feet.

The mission configuration comparison which is perhaps most indicative of the improved maximum altitude performance available with the U-2R, is the "U-2C Overload versus the U-2R Reduced T.O.G.W." (Figure 3). The U-2R has increased the range by 73 nautical miles, while it has also gained an average maximum altitude of approximately 4,790 feet.

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TABLE I

U-2R MAXIMUM ALTITUDE PERFORMANCE"OVERLOAD" TAKE-OFF WEIGHTT.O.G.W. = 36,750 LBS.NO "BADLANDS"

	D/TECH	D/TECH	LAC
Warm-up Acceleration & Take-off Fuel (Allowance), Gal.	15	15	Unknown
Reserve Fuel, Gal.	<u>150</u>	<u>100</u>	Unknown
Initial Cruise Alt., Ft.	65,000	65,000	65,050
Distance Gained in Climb, N.M.	657	657	657
End of Cruise-Climb Altitude, Ft.			
Total Distance (No credit for descent), N.M.			
Total Time to End Alt. from Lift-off, Hrs.	13.5	13.9	13.6

Note: Zero Fuel Weight = 17,400 lbs.

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TABLE II

U-2R MAXIMUM ALTITUDE PERFORMANCE

NORMAL TAKE-OFF WEIGHT

T.O.G.W. = 30,130 LBS.

NO "BADLANDS"

	D/TECH	D/TECH	LAC
Warm-up Acceleration & Take-off Fuel (Allowance), Gal.	15	15	Unknown
Reserve Fuel, Gal.	<u>150</u>	<u>100</u>	Unknown
Initial Cruise Alt., Ft.	68,240	68,240	68,240
Distance Gained in Climb, N.M.	.339	339	339
End of Cruise-Climb Altitude, Ft.			
Total Distance (No credit for descent), N.M.	3,823		
Total Time to End Alt. from Lift-off, Hrs.	9.3	9.7	9.6

Note: Zero Fuel Weight = 17,400 Lbs.

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TABLE III

U-2R MAXIMUM ALTITUDE PERFORMANCE"REDUCED" TAKE-OFF WEIGHTT.O.G.W. = 26,790 LBS.NO "BADLANDS"

	<u>D/TECH</u>	<u>D/TECH</u>	<u>LAC</u>
Warm-up Acceleration and Take-off Fuel (Allowance), Gal.	15	15	Unknown
Reserve Fuel, Gal.	<u>150</u>	<u>100</u>	Unknown
Initial Cruise Alt., Ft.			
Distance Gained in Climb, N.M.	283	283	283
End of Cruise-Climb Altitude, Ft.			
Total Distance (No credit for Descent), N.M.	2,780	2,935	2,900
Total Time to End Alt. from Lift-off, Hrs.	6.8	7.2	7.1

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NOTE: Zero Fuel Weight = 17,400 lbs.

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TABLE IV  
U-2R MAXIMUM ALTITUDE MISSION  
OVERLOAD TAKE-OFF WEIGHT

Part I

T.O.G.W. = 36,750 Lbs.	(No "Badlands")	M =	Cruise	25X1
	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up, T.O. & Acceleration	99			S.L.
Climb: S.L. to Absolute Ceiling	4,176	1.7	657	S.L./65,000
Cruise-Climb @ Absolute Ceiling	14,088	11.8		65,000/
Reserves: 150 gallons	987			
Totals	19,350	13.5		

U-2R MAXIMUM ALTITUDE MISSION

Part II

OVERLOAD TAKE-OFF WEIGHT

T.O.G.W. = 36,750 Lbs.	("Badlands" from 40K to 60K Ft.)	M =	Cruise	25X1
	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up, T.O. & Acceleration				S.L.
Climb: S.L. to Absolute Ceiling				
485°C EGT Limited Between				
40,000 and 60,000 Ft.	2,851	1.0	384	S.L./59,200
Cruise-Climb @ Absolute Ceiling				
with 485°C EGT Limitation until				
reaching 60,000 ft. altitude	1,345	1.1	434	59,200/60,000
Secondary Climb: 60,000 ft. to				
Absolute Ceiling	1,175	.7	296	60-65,700
Cruise-Climb @ Absolute Ceiling	12,893	11.0		65.7-
Reserves: 150 gallons	987			
Totals	19,350	13.8		

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TOP SECRET

25X1

25X1

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TOP SECRET

TABLE V

U-2R MAXIMUM ALTITUDE MISSION

Part I

NORMAL TAKE-OFF WEIGHT

T.O.G.W. = 30,130 Lbs.	(No "Badlands")	M = <input type="text"/>	cruise	25X1
	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up T.O. & Acceleration	99			S.L.
Climb: S.L. to Absolute Ceiling	2,431	.9	339	S.L./68,240
Cruise-Climb @ Absolute Ceiling	9,213	8.4	3,484	68,240/ <input type="text"/>
Reserves: 150 gallons	987			25X1
Totals	12,730	9.3	3,823	

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U-2R MAXIMUM ALTITUDE MISSION

NORMAL TAKE-OFF WEIGHT

Part II

T.O.G.W. = 30,130 Lbs.	("Badlands" from 40K to 60K Ft.)	M = <input type="text"/>	cruise	25X1
	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up T.O. & Acceleration	99			S.L.
Climb: S.L. to Absolute Ceiling 485°C EGT Limited Between 40,000 and 60,000 ft.	2,245	1.1	417	S.L./68,220
Cruise-Climb @ Absolute Ceiling	9,399	8.5	3,542	68,220/ <input type="text"/>
Reserves: 150 gallons	987			25X1
Totals	12,730	9.7	<input type="text"/>	25X1

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TOP SECRET

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TOP SECRET

TABLE VI

U-2R MAXIMUM ALTITUDE MISSION

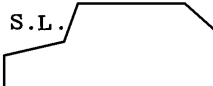
REDUCED TAKE-OFF WEIGHT

Part I

T.O.G.W. = 26,790 Lbs.

(No "Badlands")

M =  cruise

	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up T.O. & Acceleration	99			S.L.
Climb: S.L. to Absolute Ceiling	2,091	.8	283	S.L. 
Cruise-Climb @ Absolute Ceiling	6,213	6.0	2,497	
Reserves: 150 gallons	987			
Totals	9,390	6.8	2,780	

U-2R MAXIMUM ALTITUDE MISSION

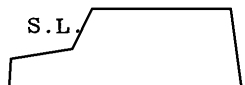
REDUCED TAKE-OFF WEIGHT

Part II

T.O.G.W. = 26,790 Lbs.

("Badlands" from 40K to 60K Ft.)

M =  cruise

	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up T.O. & Acceleration	99			
Climb: S.L. to Absolute Ceiling 485°C EGT Limited Between 40,000 and 60,000 ft.	2,441	1.1	419	S.L. 
Cruise-Climb & Absolute Ceiling	5,863	5.8	2,374	
Reserves: 150 gallons	987			
Totals	9,390	6.9	2,793	

TOP SECRET

TABLE VII

U-2C MAXIMUM ALTITUDE MISSION\*

SLIPPER TANKS ON

T.O.G.W. = 24,200 Lbs.

	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up, T.O., Acceleration & Climb	2,599	1.1	410	S.L./66,200
Cruise-Climb	6,416	5.9	2,310	66.2/
Reserves: 150 gallons	987			
Totals	10,002	7.0	2,720	

U-2C MAXIMUM ALTITUDE MISSION\*

SLIPPER TANKS OFF

T.O.G.W. = 22,900 Lbs.

	Fuel (Lbs.)	Time (Hrs.)	Distance (NM)	Altitude Feet
Warm-up, T.O., Acceleration & Climb	1,579	0.6	205	S.L./66,300
Cruise-Climb	6,120	5.8	2,255	66.3/
Reserves: 150 gallons	987			
Totals	8,686	6.4	2,460	

\*Data basis: Flight Tests as reported by Operations Division (IDEALIST)

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